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Inferring Power and Dominance from Dyadic Nonverbal Interactions in Autism Spectrum Disorder

Running Title: Power Decoding from Dyadic Interactions in Autism

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Lay Summary

This study shows that the ability and speed of judging who is dominant in a social interaction depends on two factors: (1) whether their movements are matched and (2) whether they are facing each other or not. This is similarly the case for participants with and without autism. Interestingly, however, individuals with autism seem to judge generally slower, suggesting a more explicit processing style. The two factors seem to interact, suggesting that nonverbal processing difficulties are subtler than previously thought.

Abstract

Research studies to date have revealed conflicting results with respect to the processing of nonverbal cues from social interactions in autism spectrum disorder (ASD). Therefore, the aim of the present study was to investigate the contribution of two important factors for the perception of dyadic social interactions, namely (1) the movement contingency and (2) the spatial context. To this end, 26 adult participants with ASD and 26 age-, sex- and IQ-matched typically developed (TD) control participants observed animations presenting nonverbal interactions between two human virtual characters enacting power relationships. We manipulated (1) movement contingency by exchanging one of the two original agents with an agent from another dyad and (2) spatial context by changing agents' spatial orientation to a back-to-back position. Participants were asked to rate dominance and submissiveness of these agents.

Results showed that the movement contingency manipulation affected accuracy and consistency of power perception and that the spatial context manipulation slowed down reaction times comparably in both groups. With regard to group differences, individuals with ASD were found to judge power relationships slower compared to control participants, potentially suggesting a more explicit processing style in ASD. Furthermore, the spatial context manipulation slowed down the reaction times more in the contingent compared to the non-contingent conditions only in the ASD group. These findings contribute to the ongoing debate whether individuals with ASD have difficulties in understanding nonverbal cues in a dyadic context by suggesting that they do so in more subtle ways than previously investigated.

Keywords: autism spectrum disorder; dyadic social interaction; nonverbal communication; power; dominance; submissiveness

1 Introduction

Difficulties in communication, interaction and social reciprocity are defining characteristics of Autism Spectrum Disorder (ASD) [American Psychiatric Association, 2013]. In particular, the processing of others' nonverbal cues during social interactions seems to be impaired. For instance, individuals with ASD show a decreased sensitivity to social contingencies compared to typically developed (TD) individuals: Studies using point-light displays representing two agents interacting with each other (PLDs, in which human movements are depicted solely by the kinematics of light points/markers placed on the major joints), showed that persons with ASD have difficulties categorizing social and nonsocial dyadic interactions [Centelles et al., 2013], as well as predicting an agent's behavior from the actions of another one [Von der Lühe et al., 2016]. Interestingly, the stimuli used in these studies were constrained to conventionalized gestures with learned social response expectancies, such as shaking hands or waving goodbye [confer Ware et al., 2015]. However, the social contingencies characteristic for rich communicative interactions, like conversations, are more complex and require decoding of meaning of gestures from within the context of the specific social interaction rather than mere reliance on learned response patterns [Bigelow, 1999].

In this line, a few studies on social contingency processing in ASD (i.e. the processing of spatial and temporal relationship between the behaviors of two interacting agents) have employed variations of the seminal paradigm by Heider and Simmel [1944] using animations of moving geometric shapes. These studies have shown that TD volunteers spontaneously ascribe goals, desires, intentions, and thoughts to the shapes depending on the specific movement patterns. Given that these attributions are highly replicable, they were used in ASD research to study social contingency processing. However, individuals with ASD process these animations atypically to different degrees, for example they present with inappropriate descriptions while attributing mental states to animated geometric shapes or atypical neural correlates [Abell et al., 2000, Bowler and Thommen, 2000, Castelli et al., 2002, David et al., 2010, Klin et al., 2003, Kuzmanovic et al., 2014, Zwickel et al., 2010]. A methodological limitation of this paradigm is that such synthetic animated displays are typically created via computer motion algorithms or animation techniques. McAleer and Pollick, 2008 proposed that the physical motions in these synthetic displays are not fully governed by the constrictions of actual human biological motion. To our knowledge, only three studies have thus gone further using motion patterns that were actually motion tracked from human agents and then transposed onto moving triangles [Abell et al., 2000, Edey et al., 2016] or circles [McAleer et al., 2011]. Notably, these studies show that there seems to be no difference between individuals with and without ASD in judging intentions or mental states in dyadic displays.

Given the inconsistent findings in the literature, it remains unclear whether more subtle factors actually modulate the perception of social information from dyadic social interactions in ASD. To investigate this, research needs experimental studies with stimulus material that captures the richness of motion, while at the same time allowing full experimental control and manipulation of various factors that might, individually or combined, modulate social perception. This type of rich stimulus material opens up new avenues to study the perception of subtle nonverbal cues in social interactions. Considering the above-mentioned limitations of previous paradigms used to study the processing of social information from dyadic interactions, for the present study, we have chosen to focus on a particular dimension, namely power. The perception of power from nonverbal cues follows universal, transcultural principles [Bente et al., 2010] already recognized by preverbal children [Thomsen et al., 2011]. Therefore, we identify power as a latent social phenomenon which does not rely on ritualized behaviors but which is nevertheless expressed as interpersonal contingent behavior – there is no dominance without complementary submission and vice-versa [Bente et al., 2010, Dunbar and Burgoon, 2005, Komter, 1989, Rogers-Millar and Millar III, 1979, Tiedens and Fragale, 2003]. As Schwartz and colleagues [2014] showed, ASD participants are able to identify dominance in dyadic interactions as accurately as TD participants. Therefore, the perception of power and dominance provides an ideal testbed to analyze how different factors of an interaction modulate social perception in ASD compared to TD. We therefore used stimulus animations with naturalistic movement-behavior [Bente et al., 2008, Bente et al., 2010, Georgescu et al., 2014].

The perception of social interactions crucially depends on temporal contingencies and reciprocal movement patterns between two agents [Burgoon et al., 1993, Burling and Lu, 2018, Manera et al., 2011a, 2011b, Moran et al., 1992, Neri et al., 2006, Thurman and Lu, 2014]. A further prerequisite for the perception of a social interaction is that their actions are in physical proximity, mutually oriented and attending one another [Quadflieg and Koldewyn, 2017]. However, the extent to which our perception of rich, complex and non-conventionalized social interactions (neither sport/game related nor a short ritualistic exchange, like a greeting) is dependent on these two factors has not been systematically looked at in an experimental context before, neither in typical nor in atypical development. The aim of this present study was therefore to explore the relevance of these two factors: (1) movement contingency and (2) spatial context for the perception of rich nonverbal social interactions in ASD and TD individuals. We therefore manipulated movement contingency on the one hand and spatial context on the other in a 2x2 design. Movement contingency was manipulated by creating an animation category of artificial dyads, including exchanged agents from different dyads. Spatial context was manipulated by creating a stimulus category in which agents were seated back-to-back. The animations used are experimentally controllable, ecologically valid and allow better anonymization and standardisation in comparison to videos. To our knowledge, this is the first study that explores the effects of these two factors on the perception of social information from dyadic interactions in ASD.

We hypothesized that ASD participants show a similar accuracy (H1) and consistency (H2) during power judgments of observed social interactions [Schwartz et al., 2014].

We further assumed that TD individuals' accuracy, consistency and reaction times are decreasing when either the relational information or the contextual information are manipulated independently or together (H3) but that this is not the case for ASD participants (H4). Finally, based on previous findings showing rather explicit social cognitive processing in ASD [Kuzmanovic et al., 2011], ASD participants are expected to show slower reaction times in their judgement ratings compared to TD (H5).

2 Method

2.1 Participants

A group of 26 persons with ASD and a group of 26 age-, sex- and verbal IQ-matched TD control persons participated in this study (see Table 1). All participants had normal or corrected-to-normal vision, signed an informed consent form before participation and received a monetary compensation of 10 euro per hour. This study was part of a larger battery of studies that were performed during the course of half a day (with breaks). The study was approved by the local ethics committee of the Medical Faculty of the University of Cologne and is in line with the Declaration of Helsinki.

The 26 ASD participants (14 male) were between 29 and 56 years of age (M = 45.81; SD = 7.13) and were diagnosed and recruited at the Autism Outpatient Clinic of the Department of Psychiatry, University Hospital Cologne, Germany. We included both male and female participants, as we did not specifically manipulate sex in the study design. The sample included only patients with the diagnoses high-functioning autism (ICD-10: F84.0) or Asperger syndrome (ICD-10: F84.5). Two medical specialists confirmed the diagnosis independently in clinical interviews, according to the criteria of the International Classification of Diseases (ICD-10) and supplemented by extensive neuropsychological examination. Furthermore, all ASD participants showed an at least average verbal IQ (minimum=85) measured by the "Wortschatz-Test" (WST) [Schmidt and Metzler, 1992]. Nine ASD participants received psychotropic medication (Citalopram: 2; Escitalopram 1; Paroxetin: 1; Clomipramin: 1; Elontril: 1; Elontril and Citalopram: 1; Nortrilen: 1; Valproic acid: 1; Medikinet: 1).

The 26 TD participants (14 male) were between 27 and 59 years of age (M = 42.88; SD = 8.07) and were recruited online from the students and staff population at the University Hospital Cologne and via the participant volunteer pool of the Department of Psychiatry of the University Hospital Cologne. They reported no history of psychiatric or neurologic disorders and no intake of psychotropic medications (except one participant taking Lithium as a long-term migraine prophylaxis). To ensure that control participants did not have significant autistic traits, the Autism Questionnaire (AQ) [Baron-Cohen et al., 2001] cut-off score in the TD group was 26 as recommended by Woodbury-Smith and colleagues [2005].

In both groups, intelligence was measured by the German multiple-choice IQ test “Wortschatz-Test” (WST) [Satzger et al., 2002, Schmidt and Metzler, 1992]. This valid and quick IQ test has been used for group matching in previous ASD research before [Georgescu et al., 2013, Kuzmanovic et al., 2014, Schilbach et al., 2012]. Additionally, we administered the following questionnaires to all participants: German versions of the Beck Depression Inventory (BDI) [Beck and Steer, 1987, Hautzinger et al., 1995], the Empathy Quotient (EQ) [Baron-Cohen and Wheelwright, 2004], the Systemizing Quotient (SQ) [Baron-Cohen et al., 2003], as well as the Short Multichannel Version of the Profile of Nonverbal Sensitivity (miniPONS) [Bänziger et al., 2011].

[*Insert Table 1 here*]

2.2 Stimuli

The stimulus material consisted of ten 10 s long silent animations showing two seated virtual characters engaged in a conversation. The ecological validity was ensured by transcribing the movement behavior from real videotaped dyadic interactions onto virtual characters. The original stimulus material pool had been previously validated in studies on nonverbal perception in both TD and ASD [Bente et al., 2008, Bente et al., 2010, Georgescu et al., 2014, Schwartz et al., 2014].
The virtual characters used were two virtual manikin models. While PLDs have been extensively used in the past in biological motion studies, they are not considered as appropriate when studying the effects of more complex motion information, as is the case for full-body dyadic nonverbal behavior [Chaminade et al., 2007, Hodgins and Wooten, 1998]. Thus, by using virtual manikins, we could anonymize and standardize the appearance of all actors, while still ensuring that the fully-rendered models were robust enough to carry the full kinematic information.
The important advantage of using virtual characters as opposed to real videos of people lies in the option of systematic manipulation of various factors of interest like movement contingency and spatial context (see point 2.3). Importantly, research has found comparable impression formation in TD in situations when they are watching videotaped human dyadic interactions just as in situations when they observe the same interactions as virtual animations [Bente et al., 2001].

2.3 Study Design

Two main factors of interest were systematically manipulated on two levels each: (1) movement contingency (contingent movements vs exchanged agent) and (2) spatial context (face-to-face vs back-to-back) as two within-participant factors with group as between-participant factor (ASD vs TD), resulting in a 2x2x2 mixed design (see Figure 1).

[*Insert Figure 1 here*]

First, we manipulated movement contingency by substituting the agent seating on the right side of each original dyad by another agent from a different dyad. Second, to manipulate spatial context, the position of the two agents was changed from face-to-face to back-to-back. This resulted in 4 conditions (ORIG, the original animations where agents' movements are contingent and they are facing each other; EX, animations were manipulated such that agents would still be facing each other, but one agent was exchanged to break contingency; B2B, the original animations were manipulated such that the agents are facing away from each other; and EXB2B, where the agents are not only exchanged but are also seated back to back) that were presented in 10 different animations per conditions, summing up to a total of 40 animations. In the following, we use abbreviations for each experimental condition as depicted in Figure 1.

To avoid movement intensity differences between the original and the manipulated dyads, we carried out a motion energy analysis using a custom-made MATLAB quantification algorithm (Version R2016b, The MathWorks, Inc., Natick, MA; www.mathworks.com). Additionally, to match the exchanged agents for dominance scores and to validate the position of the rather dominant agent, we conducted a pre-study with 10 TD participants. For results and details, please see supplementary materials.

2.4 Experimental Procedure

Before the experiment, participants were familiarized with the task performance in a standardized computer-based instruction and practice session. None of the animations shown in the introduction were used in the subsequent experiment. Participants were told that they would see 10 s lasting silent motion-captured animations of two interacting characters. No further information about the nature of the videos or of the manipulations was given, in order not to bias their perception. It was assumed that viewers would infer a relationship among people presented simultaneously on the screen, across manipulations [Iacoboni et al., 2004]. They were also told that they would be asked to rate the stimuli after each one by pressing the corresponding keyboard button. Each of the 40 animations was presented in two repetitions, once in their original position and once with swapped positions, so that each of the two agents of any dyad was presented equally often on either side of the screen. This resulted in 20 trials per condition, summing up to 80 trials. In addition, each of the resulting 80 animations was presented twice, followed either by the question who of the two agents was rather dominant, or the question who was rather submissive. This eventually resulted in 160 trials in total that were randomized across the experiment. The experiment was split into two blocks of 80 trials each, lasting for about 20 minutes respectively with a short break in between.

Each experimental trial consisted of the 10 s animation followed by two questions. The first question was counter-balanced, either ”Who was rather dominant?“ or ”Who was rather submissive?“ with a six-point-scale ranging from -3 (“clearly left person“) to +3 ”clearly right person”). A second question always followed the dominance/submissiveness judgement, namely ”How pronounced?“ on a six-point-scale from 1 (“very little“) to 6 (“very much“). This second question will be disregarded in the following as it was implemented for comparison with a separate paradigm on individual agent perception, to be reported elsewhere. A fixation cross appeared for 2 seconds before each animation and for 0.5 seconds before each scale. Participants were instructed to focus on the fixation cross between the trials and to pay attention to both agents while watching. They were further asked to respond as quickly and intuitively as possible after the display of the scale. No feedback on performance was given after each trial. Stimulus presentation and response recording were implemented using the software package Presentation (Version 17.2, Neurobehavioral Systems, Inc., Berkeley, CA, www.neurobs.com).

After the experiment and to control for group differences regarding the general naturalness of stimuli, participants were asked to complete a post-test questionnaire and were given opportunity for giving general feedback on the study (for more information, please see supplementary materials).

2.5 Statistical Analysis

All analyses were conducted using SPSS Statistics (Version 24, IBM Corp., Armonk, NY, www.ibm.com) and Bayes Factors were added using JASP [JASP Team, 2018] where they aided the results interpretation. First, we analyzed participants’ accuracy of perception of both groups (ASD and TD) across the experimental conditions. Second, we looked at the corresponding mean reaction times (RTs). Third, we focused on participants’ consistency of perception by analyzing mean rating deviations between the “ORIG” animations and each of the manipulations (“B2B”, “EX” and “EXB2B”).

For the first two main analyses, dependent variables were ratings and RTs. For the third one, the dependent variable was mean rating deviation to the original rating baseline. Analyses were performed aggregated over both, dominance and submissiveness scores, given that power relationships are considered to be complementary – there is no dominance without submission and vice-versa [Bente et al., 2010, Dunbar and Burgoon, 2005, Komter, 1989, Rogers-Millar and Millar III, 1979, Tiedens and Fragale, 2003]. Participants’ rating scores for each swapped animation (the control so that each of the two agents of any dyad was presented equally often on either side of the screen) were first re-coded (i.e. left side of the scale would be right side) in order to enable averaging over the two versions of each animation. Ratings and RTs were extracted from the raw output files of the stimulus presentation software using a custom-made MATLAB script. If a participant's mean rating (across the two presentation types: normal and swapped) for an animation was < 3.5 (on a six-point-rating-scale), we categorized it as "left agent", if it was > 3.5 as "right agent". A mean rating of exactly 3.5 was categorized as "uncertain", indicating inconsistent ratings of the same animation across the two versions. This allowed us to calculate for each individual animation the frequency with which either the left or the right agent had been chosen as the dominant (or submissive) one.

First, to analyze accuracy of power perception, we calculated the frequency of "correct identification". The "correct identification" of power was determined by dominance ratings in the pre-study (see point 2.3 and supplementary materials). For example, if participants answered the question of submissiveness with "left agent" (< 3.5), the answer was coded as "correct", if the left agent had been rated as less dominant than the right one in the pre-study. If in that same case, they chose "right agent" (> 3.5) or if the average rating was exactly 3.5, it was not coded as "correct". Second, to analyze participants' RTs, we calculated the mean value of RTs of ratings for every participant and for each condition ("ORIG", "B2B", "EX", "EXB2B"). Third, to analyze consistency of perception, irrespective of accuracy, we calculated the deviation in rating scores between the ratings given for the animations in the "ORIG" condition and those for each of the other conditions by subtracting the average-rating in each original animation from the average-rating in each manipulated animation ("ORIG"-"B2B" = "B2B_d"; "ORIG"-"EX" = "EX_d"; "ORIG"-"EXB2B" = "EXB2B_d") for both groups. Then, to analyze overall consistency of perception, we computed the mean over all absolute deviation values of both scales (dominance and submissiveness) over all animations in each condition.

To test for significant differences between conditions and groups across dependent variables in the three analyses, we conducted a series of analyses of variance (ANOVAs). For details of each ANOVA, please see results section. Kolmogorov-Smirnov tests revealed that several variables did not meet the condition of normality, however, neither of these were severe and values for asymmetry and kurtosis were well between -2 and +2 [George and Mallery, 2010]. Moreover, ANOVA is a robust test against the normality assumption. Simulation studies, using a variety of non-normal distributions, have shown that ANOVA tolerates violations to its normality (skewed or kurtotic distributions) with only a small effect on the type I error rate (the false positive rate) [Blanca et al., 2017, Glass et al., 1972, Harwell et al., 1992, Lix et al., 1996]. If Mauchly's test indicated that the assumption of sphericity was not fulfilled ($p < .05$), degrees of freedom were corrected using the Greenhouse–Geisser estimates of sphericity. All effects are reported as significant at $p < .05$ and as trends at $p < .1$.

3 Results

3.1 Accuracy of Power Perception

We performed a two-way mixed ANOVA for “correct identification”, defining CONTINGENCY (movement contingency: contingent movement vs exchanged agent) and CONTEXT (spatial context: face-to-face vs back-to-back, see Figure 1) as within-subject independent variables, GROUP (ASD or TD) as a between-subject variable and the frequency of “correct identification” as a dependent variable. One-way ANOVAs (Bonferroni-Holm corrected) [Holm, 1979] were used as post-hoc test to compare pairwise all the different experimental conditions.

There was a significant main effect of CONTINGENCY ($F(1, 50)= 10.399$, $p= 0.002$, $\eta 2p= 0.172$, $BF_{10} = 22.46$), showing that participants were significantly more accurate in the non-contingent conditions (“EX” and “EXB2B”) than in the contingent conditions (“ORIG” and “B2B”) across both groups and irrespective of spatial context (see Table 2 and Figure 2). The Bayes factor for this test indicates strong evidence in favor of the effect. An analysis of simple effects showed that this contingency effect was significant for the TD group, $F(1,25) = 11.22$, $p < 0.001$, $BF_{10} = 26.57$ but not for the ASD group, $F(1,25) = 1.02$, $p = 0.32$, $BF_{10} = 0.331$. In other words, the difference between the non-contingent and contingent conditions in the TD group seems to drive the main effect of movement contingency. An inspection of Figure 2 suggests that the ASD participants tend to be more accurate than the TD group particularly in the contingent compared to the non-contingent conditions. The difference was reflected in a trend for an interaction between CONTINGENCY and GROUP ($F(1, 50)= 12.505$, $p= 0.059$, $\eta 2p= 0.070$, $BF_{10} = 12.36$). The Bayes factor for this test indicates that the data are 12.36 more likely to be observed under the alternative hypothesis, in other words, it indicates strong evidence in support of the effect. There were no other significant main effects or interactions (smallest $p=.238$).

[*Insert Table 2 here*]
[*Insert Figure 2 here*]

3.2 Reaction Times

We performed a three-way mixed ANOVA with CONTINGENCY (movement contingency: contingent movement vs exchanged agent) and CONTEXT (spatial context: face-to-face vs back-to-back, see Figure 1) as within-participant variables and GROUP (ASD or TD) as between-participants variable and the mean RTs as dependent variable.
Results showed a main effect of GROUP ($F(1, 50)=11.201$, $p=.002$, $\eta 2p=.183$, $BF_{10} = 18.57$) with longer reaction times in ASD than TD (see Table 3) and a main effect of CONTEXT with increased RTs when the spatial context was back-to-back (“B2B” or “EXB2B”), compared to face-to-face (“ORIG” or “EX”) ($F(1, 50)=55.89$, $p=.000$,

η2p=.528; BF_{10} = 3.989e+9 Figure 3). Finally, we found an interaction between CONTINGENCY*CONTEXT*GROUP (F(1, 50)=6.032, p=.018, η2p=.108, BF_{10} = 1.214e+10), suggesting that spatial context impacts the reaction time differently on the levels of CONTINGENCY but only in the ASD group (see Figure 3). Inspecting Figure3, ASD show longer RTs for when contingent videos are back-to-back compared to when they are face-to-face. There were no other significant main effects or interactions (smallest p=.661). An analysis of simple effects showed that this interaction effect was significant for the ASD group, $F(1,25) = 7.36$, $p < .05$, BF_{10} = 1630.632 but not for the TD group, $F(1,25) = 0.31$, p = .58, BF_{10} = 5480.423.

[*Insert Table 3 here*]
[*Insert Figure 3 here*]

3.3 Consistency of Power Perception

We performed a two-way mixed ANOVA with MANIPULATION (three conditions: "B2B_d", "EX_d" or "EXB2B_d") as within-subject independent variable, group (ASD or TD) as a between-subject variable and deviation means as a dependent variable.
There was a main effect of MANIPULATION F(2, 49)=16.756, p=.000, η2p=.251 and post-hoc pairwise comparisons (Bonferroni corrected) showed significant differences between "B2B_d" and "EX_d" (p=.000, SE= .058) and between "B2B_d" and "EXB2B_d" (p=.000, SE=.056), but not between "EX_d" and "EXB2B_d" (p=1, SE=.047). As Figure 4 shows, participants were significantly more consistent in their ratings for the contingent manipulation ("B2B_d") than for the non-contingent manipulations ("EX_d" and "EXB2B_d"). No significant group difference or interactions were found (smallest p=.724).

[*Insert Figure 4 here*]

4 Discussion

The present study focused on the investigation of the contribution of two important factors, namely movement contingency and spatial context, for the perception of social interactions in ASD and TD. For this purpose, we presented short silent animations of interactions between two virtual characters, and the dependent variables were concerned with the accurate and consistent perception of power cues.

Results showed comparable accuracy and consistency of power judgements for both diagnostic groups. Surprisingly, the non-contingent conditions increased accuracy performance, but decreased consistency. The second factor, spatial context, had no significant impact on perception accuracy, but it did have an effect on RTs with the back-to-back agent conditions requiring longer RTs. The only group differences we found were overall longer RTs for the ASD group compared to the TD group. Additionally, spatial context affected RTs differentially on the levels of the factor movement contingency, but only in individuals with ASD: A significant three-way interaction effect showed that the back-to-back spatial context increased RTs for contingent dyads more than for non-contingent ones in the ASD group only. The implications of these results are discussed below.

4.1 Both Factors Matter for Processing Power Judgements: Movement Contingency for Accuracy and Spatial Context for Speed

We found that out of the two investigated factors, it is movement contingency rather than spatial context which affects the perception of nonverbal communicative interactions. This is in accordance with past implications of the importance of movement contingency for communicative interactions [Centelles et al., 2011, Fedorov et al., 2018, Georgescu et al., 2014, Manera et al., 2011a, Manera et al., 2011b, Quadflieg and Koldewyn, 2017]. Both, accuracy and consistency of power judgements, were affected by the contingency manipulation, however in different ways: On the one hand the non-contingent conditions increased accuracy, but they decreased consistency on the other.

With regard to the first finding, power is assumed to be an interpersonal feature [Dunbar and Burgoon, 2005]. Nevertheless, in the present study, virtual characters lacked any verbal or facial information. In particular, information about eye-movements and gaze direction is informative to person perception in general [Georgescu et al., 2013, Kuzmanovic et al., 2009, Pfeiffer et al., 2012] and power perception in particular [Dovidio and Ellyson, 1982, Dunbar and Burgoon, 2005]. For instance, there are findings showing the importance of visual dominance behavior, implying that less dominant people look less directly to interactants while speaking than while listening [Dovidio and Ellyson, 1982]. Moreover, bodily and facial nonverbal signals show mutual influences [De Gelder et al., 2010, Van den Stock et al., 2007]. What is more, traits of power do also appear in individual behavior, like for example domineeringness, which is a kind of individual counterpart of dominance and denotes behavior patterns of individualistic “one-up” messages [Courtright et al., 1979]. Some individual gestures of power and dominance like lifted head or opened extremities appear to be cross-culturally important for power perception in dyads [Bente et al., 2010]. Despite the social coherence of such dyadic displays, it is possible that in the non-contingent conditions, individual cues become more salient due to the lack of temporal correlations or reciprocity, which may reveal that the two agents do not belong together. Future eye-tracking studies would help to elucidate if participants’ watching behavior was related to such individual gestures and if their visual perception strategy differed between conditions with contextual and relational stimulus manipulations.

On the finding of decreasing consistency in non-contingent conditions, it is worth noting that for the consistency analysis, the reference were the ratings for the original animations (face-to-face and contingent). Therefore, irrespective of the actual accuracy of judgements, the two non-contingent manipulations achieved worse rating consistency compared to the contingent back-to-back condition. Though speculative, it could be that social coherence helps participants with consistent judgement.
Spatial context had no significant impact on perception accuracy in both groups, as measured by the explicit judgement ratings, but on the more implicit measure of reaction times, the back-to-back agent conditions took longer to judge. This may suggest that a more effortful integration of perceived behaviors is needed in these conditions. Alternatively, the spatial context manipulation was more obvious and/or unusual or surprising and this alone might have affected judgement speed in a top-down manner. Moreover, back-to-back sitting agents might even carry a completely different connotation, like "conflict" or they may seem to be interacting with partners outside of the screen. However, our post-test questionnaire included one open ended question: „Did you notice anything particular about the agents or their movements (either negatively or positively), which you would like to mention? ". None of the answers to this question mentioned the difference between manipulations or the fact that they found back-to-back sitting agents less credible. Therefore, we attribute the difference in reaction times to the cognitive processing related to reframing of back-to-back orientated behavior patterns while watching the animations with manipulated interaction context.

4.2 Group Differences: Power Judgements of Individuals with ASD Take Longer and Are Modulated by Movement Contingency and Spatial Context

In accordance with our hypotheses and corroborating the findings of Edey and colleagues [2016], Schwartz and colleagues [2014] and McAleer and colleagues [2011], analyses of accuracy (H1) and consistency (H2) of perception were comparable in ASD and TD. This suggests that social perception in ASD is intact. Moreover, social perception in ASD is also comparably modulated by manipulating the two defining factors of social interactions: movement contingency and spatial context. According to our hypothesis (H3), we also found decreasing consistency of perception and RTs when either the relational information or the contextual information are manipulated independently or together. Contrary to our hypothesis (H4), this was also the case in ASD. This is the first time that an investigation of more subtle interaction factors in ASD was attempted.

However, looking at a more implicit measure, namely participants' RTs, we found a main effect of group in accordance with our hypothesis (H5), namely that judgements were slower in the ASD compared to the TD group. Given that a recent meta-analysis by Ferraro [2016] found no evidence for a generally slower cognitive processing style in ASD, we interpret the current finding as showing that social cognitive processing requires additional effort and a more "explicit" reasoning from individuals with ASD as opposed to a more “implicit” and “immediate” perception in TD persons. In this line, a recent study by Fedorov and colleagues [2018] argues that, in TD individuals, there is a specialized representation for encoding contingent social interaction. The authors speculate that this representation is impaired in ASD. In this line, the longer RT in the present study might indicate a need to rely on different mechanisms to recover automatic encoding of social interaction contingencies.

Interestingly, the TD group tend to have lower accuracy compared to ASD (as seen in 3.1 and Figure 2) but they also are significantly faster (3.2 and Figure 4). This could be indicative of a selective speed-accuracy trade-off in this group. A subsequent correlation analysis, however, showed no correlation of speed and accuracy in the TD group ($r = -0.008$, $p = .97$) and the scatterplots and regression lines confirmed that such a trade-off was not present.

Moreover, while TDs were slowed down by the back-to-back spatial context manipulation in equal measure, irrespective of whether they were watching contingent or non-contingent animations, this was not the case for the ASD group, where the increase in reaction time from face-to-face to back-to-back was even greater in the contingent compared to the non-contingent condition. This selective slowing down of ASD ratings is surprising. First, both groups are possibly trying to bring the actions of the two agents together under more adverse conditions in the B2B condition, in order to judge a dyadic trait like dominance. But this seems to be even harder for individuals with ASD in the condition with missing reciprocity (i.e. when agents have been exchanged). Due to their cognitive style biased toward local information processing [Happé, 1999, Dakin and Frith, 2005], it might be that the requirement to judge an interpersonal feature like dominance and the instruction to pay attention to both agents pose an even greater difficulty to them in the EXB2B condition, as they strive to bring the actions of two agents together in a condition where the agents are neither oriented toward one another, nor are there any temporal correlations between their movements. We do not find this in the TD group potentially because TD individuals tend to automatically perceive social coherence when they see two agents facing each other on screen [see also Iacoboni et al., 2004], irrespective of whether their actions are reciprocal or not. They therefore reach their judgements just as slow in both contingent and non-contingent back-to-back conditions.

Even though participants were instructed to focus their attention on both agents in each dyad, we did not have eye-tracking implemented to ensure that this was indeed the case. Hence, it could be speculated that the ASD group would show a different visual scanning behavior while watching the interactions and extracting different cues to power judgements and decoding the agents’ movements. Based on previous research, however, we have reason to believe that this was not the case: Social cognition research in ASD participants that has previously used nonverbal dyadic interactions as stimuli, has revealed a similar gaze behavior compared to that of TD participants [Von der Lühe et al., 2016, Zwickel et al., 2010]. The general consensus is that detection and early processing of social agent information in ASD are intact, but that differences between ASD participants and TD participants are more likely to be lying at later stages of processing where information has to be integrated to interpret a behavior or form an impression based on it [Georgescu et al., 2013, Zwickel et al., 2010]. Assuming that all participants were compliant with the instructions in the present study, we can conjecture that, in terms of visual strategies, at least all participants payed attention to both agents of a dyad across all conditions. Furthermore, the question for the rating followed each video, which meant that participants could not prepare a strategy in advance for dominant versus submissive behavior.

5 Conclusions

Interaction between two agents' movements and their mutual orientation to each other are essential prerequisites for a full understanding of dyadic interactions. In order to better understand the contribution of these factors to social processing in ASD and TD, we compared the effects of the manipulation of (1) movement contingency and (2) spatial context on interaction perception in ASD and TD employing animations showing interpersonal behavior enacting power relationships with high ecological validity. As a main result we found, as expected, that ASD individuals show a comparable accuracy and consistency in perceiving power compared to TD individuals but slower RTs, potentially indicative of a more explicit processing style. A further group difference was found in that the reaction times of the ASD group but not the TD group were affected by the interaction of the two manipulated factors characterizing dyadic relationships: (1) movement contingency and (2) spatial context. In conclusion, the present study used a novel paradigm to show that the often reported atypicalities in ASD are more subtle and multifaceted than previously assumed.

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Tables

Table 1.
Demographic and Neuropsychological Data.

	ASD participants				*TD participants*				*Statistics*		
Gender (m:f)	14:12				14:12						
	M	*SD*	*min*	*max*	*M*	*SD*	*min*	*max*	*df*	*t*	*p*
Age (y)	45.81	7.13	29	56	42.88	8.07	27	59	50	1.38	.172
Education (y)	19.15	4.14	12	28	18.37	4.53	11	30	50	.66	.515
WST IQ	112.23	10.46	88	129	112	11.31	84	133	50	.077	.939
BDI	12.12	7.17	1	30	2.96	2.85	0	10	32.71	6.05	**.000***
AQ	42.62	4.23	27	49	15.5	4.79	8	24	50	21.64	**.000***
EQ	16.08	7.61	5	31	49.19	12.49	25	77	50	-11.55	**.000***
SQ	43	14.29	17	65	23.04	7.93	10	37	39.06	6.23	**.000***
miniPONS	48.32	5.48	37	57	49.54	4.38	37	56	49	-.88	.384

Abbreviations: ASD, autism spectrum disorder; TD, typically developed; m, male; f, female; y, years; *M*, mean; *SD*, standard deviation; *df*, degrees of freedom; WST, “Wortschatz-Test”, estimate of verbal intelligence; BDI, Beck Depression Inventory; AQ, Autism Spectrum Quotient; EQ, Empathy Quotient; SQ, Systemizing Quotient; miniPONS, Short Multichannel Version of the Profile of Nonverbal Sensitivity.
Notes: miniPONS values refer to the amount of correct answers, miniPONS data of one ASD participant are missing.
* denotes significance on $p < .001$ level.

Table 2.
Frequency of Correct Identification.

		ASD participants			*TD participants*		
		M	*SD*	*SE*	*M*	*SD*	*SE*
Correct Identification	"ORIG"	12.54	2.53	0.5	11.12	3.05	0.6
	"B2B"	12.54	3.43	0.67	11.27	2.82	0.55
	"EX"	13.15	3	0.59	12.73	3.77	0.74
	"EXB2B"	12.58	3.52	0.69	12.27	3.86	0.76

Abbreviations: ASD, autism spectrum disorder; TD, typically developed; *M*, mean; *SD*, standard deviation; *SE*, standard error; "ORIG", original animation; "B2B", back-to-back; "EX", exchanged agent; "EXB2B", exchanged agent and back-to-back.

Table 3.
Reaction Times of Ratings (ms).

	ASD participants			*TD participants*		
	M	*SD*	*SE*	*M*	*SD*	*SE*
ORIG	2251	323.5	63.4	1981.7	236.8	46.4
B2B	2491.4	373.4	73.2	2121.2	411.9	80.8
EX	2308.1	387.5	76	1965.3	275	53.9
EXB2B	2402.9	469.6	92.1	2129	363.2	71.2

Abbreviations: ms, milliseconds; ASD, autism spectrum disorder; TD, typically developed; *M*, mean; *SD*, standard deviation; *SE*, standard error; ORIG, original animation; B2B, back-to-back; EX, exchanged agent; EXB2B, exchanged agent and back-to-back.
Note: Means of reaction times were rounded to one decimal place with respect to the resolution of the presentation software (0.1 ms).

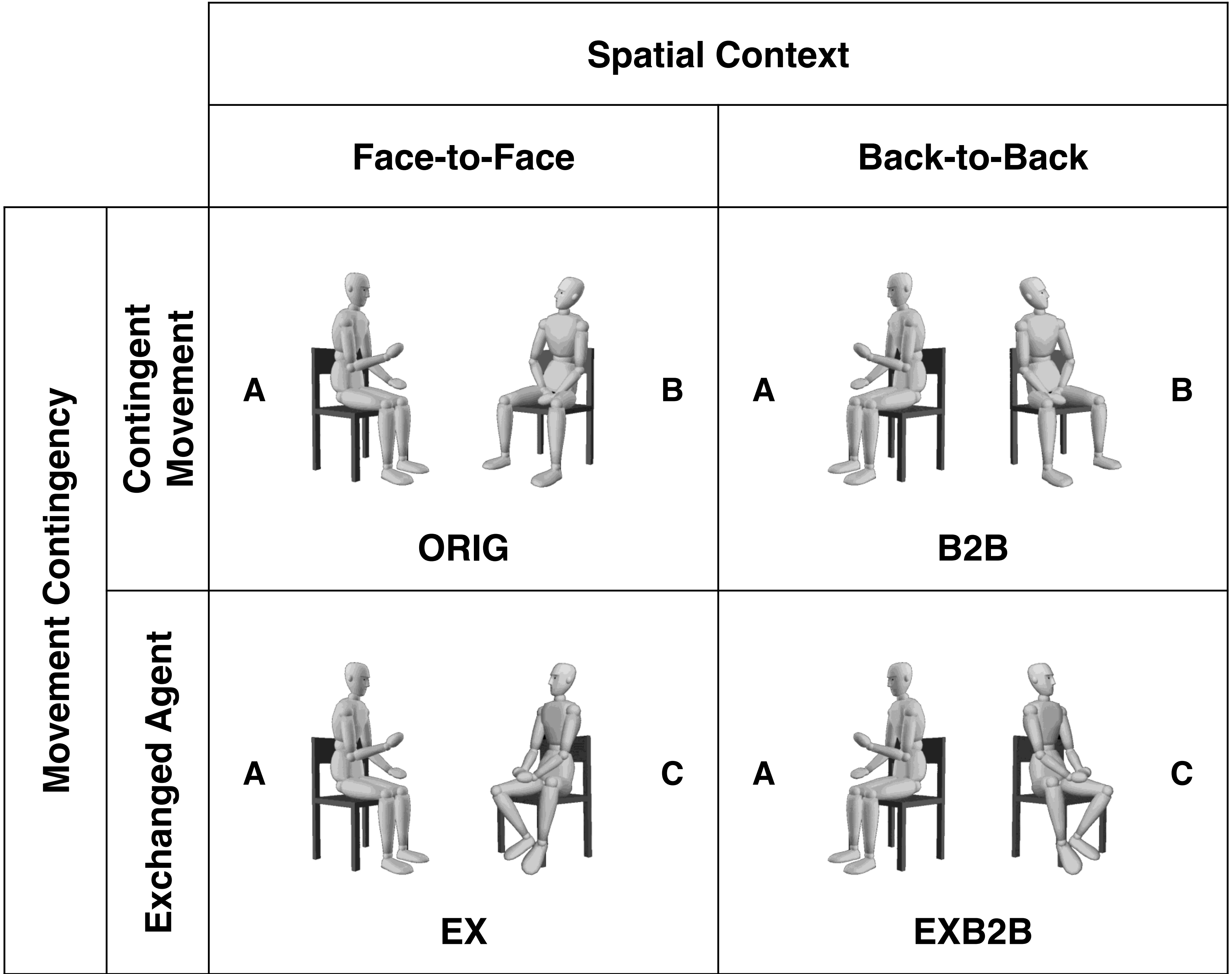
Figure Legends

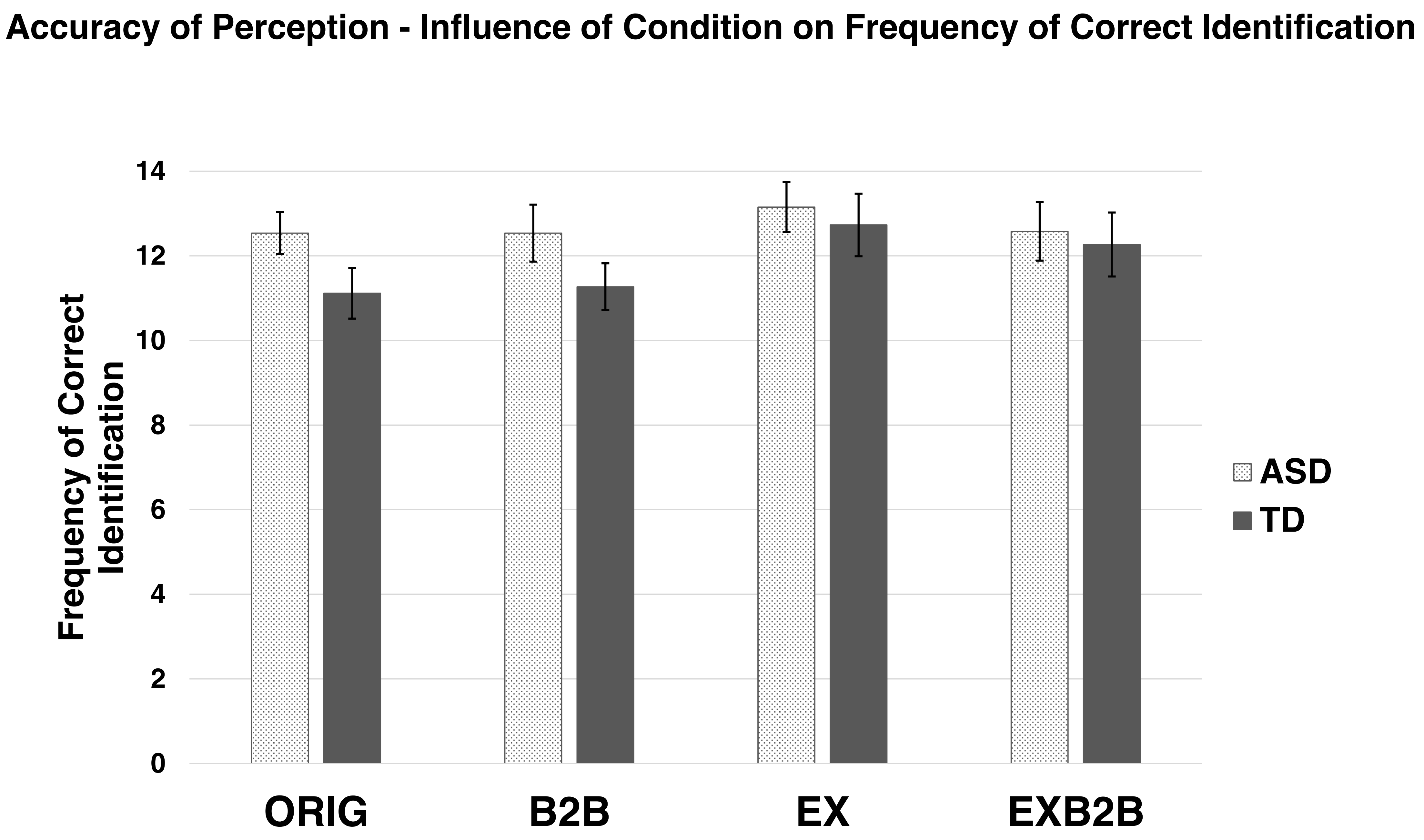
Figure 1. Stimulus Conditions. ORIG, original animation (movement contingency unchanged, spatial context unchanged); B2B, back-to-back (movement contingency unchanged, spatial context manipulated); EX, exchanged agent (movement contingency manipulated, spatial context unchanged); EXB2B, exchanged agent and back-to-back (movement contingency manipulated, spatial context manipulated); A, agent A; B, agent B; C, agent C.

Figure 2. Accuracy of Power Perception - Influence of Condition on Frequency of Correct Identification. ASD, autism spectrum disorder; TD, typically developed participants; ORIG, original animation; B2B, back-to-back; EX, exchanged agent; EXB2B, exchanged agent and back-to-back. Bars are standard errors. Maximal achievable frequency of correct identification was 20.

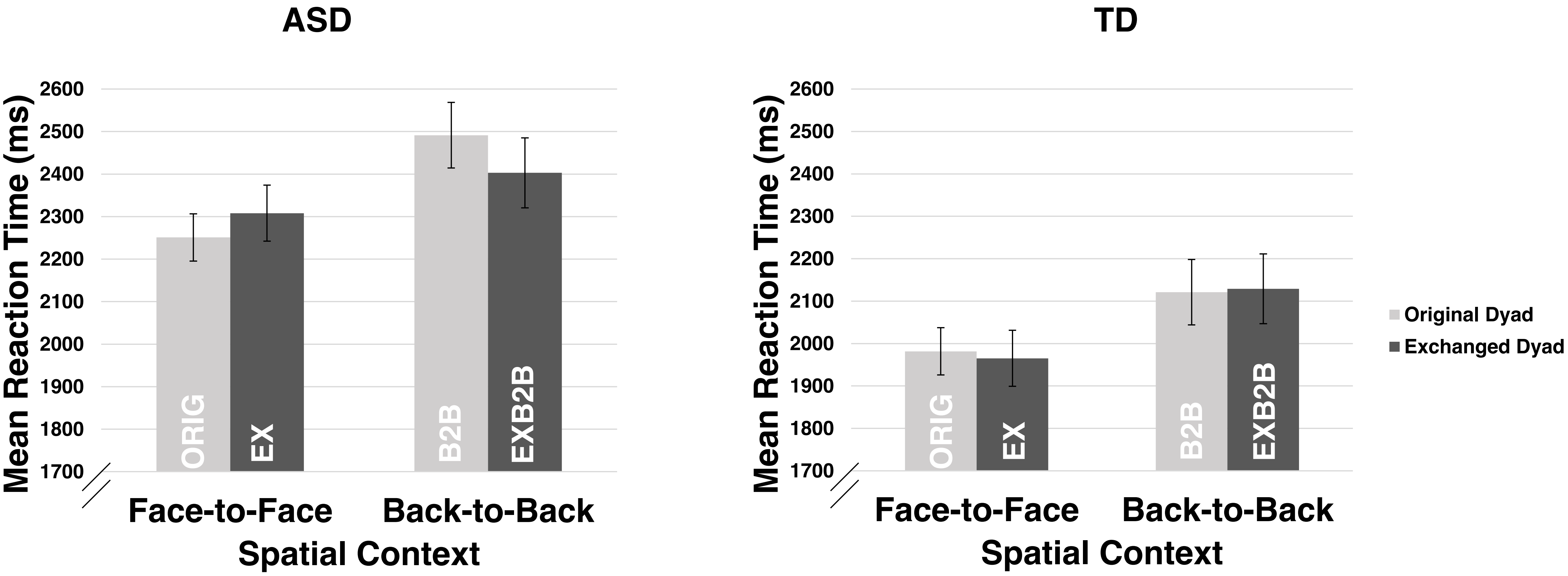
Figure 3. Reaction Times of Ratings – Interaction Between CONTINGENCY*CONTEXT*GROUP. ASD, autism spectrum disorder; TD, typically developed participants; CONTINGENCY, movement contingency (original dyad vs. exchanged dyad); CONTEXT, spatial context (face-to-face vs. back-to-back); ORIG, original animation; B2B, back-to-back; EX, exchanged agent; EXB2B, exchanged agent and back-to-back; ms, milliseconds. Bars are standard errors.

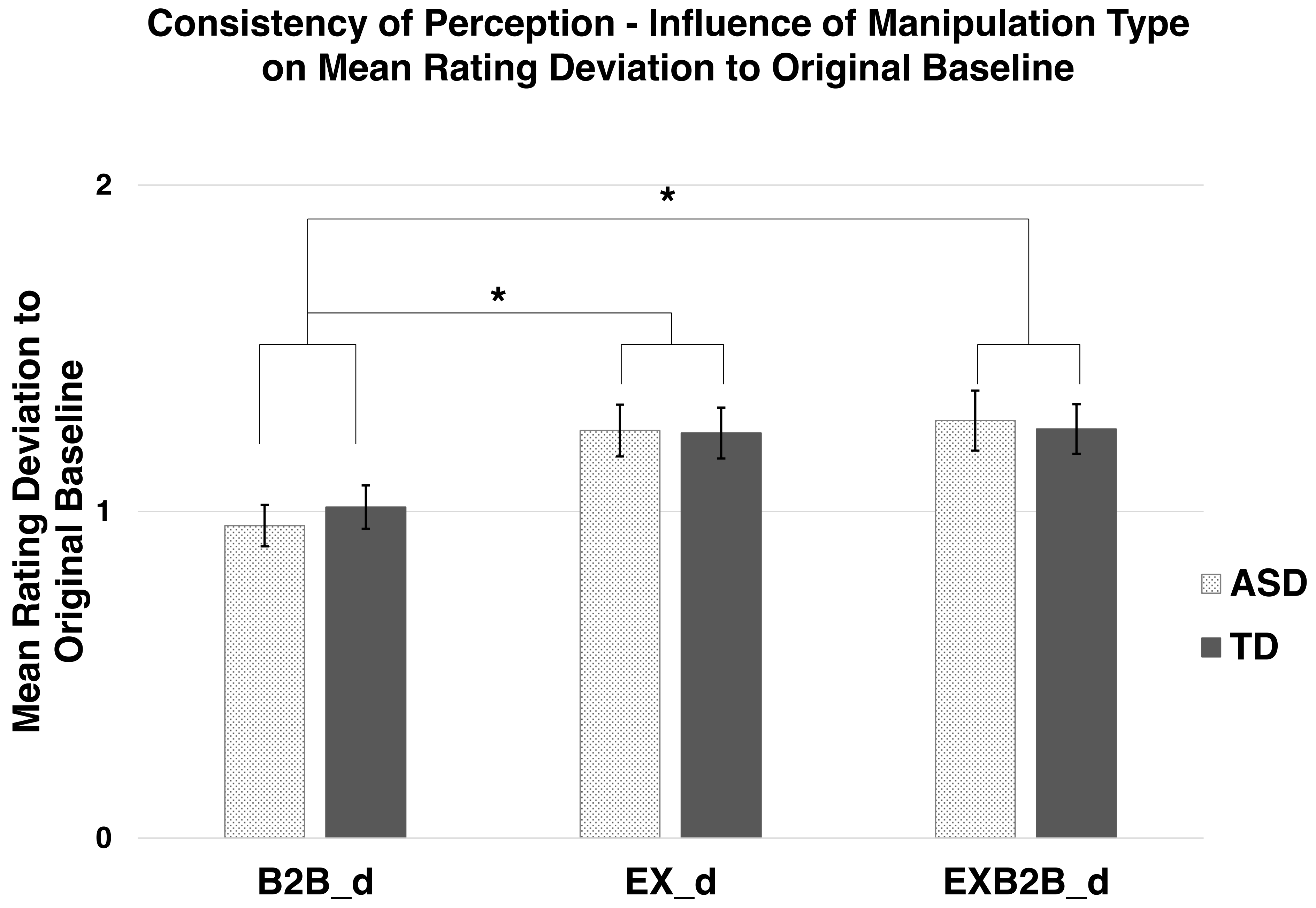
Figure 4. Consistency of Perception - Influence of Manipulation Type on Mean Rating Deviation to Original Baseline. ASD, autism spectrum disorder; TD, typically developed participants; B2B_d, back-to-back (mean rating deviation to original baseline), EX_d, exchanged agent (mean rating deviation to original baseline); EXB2B_d, exchanged agent and back-to-back (mean rating deviation to original baseline). Bars are standard errors. Maximum achievable mean rating deviation was 5. * denotes significance on $p < .005$ level.


Spatial Context
Face-to-Face
Back-to-Back
Movement Contingency
Contingent Movement
Exchanged Agent
A
B
ORIG
A
B
B2B
A
C
EX
A
C
EXB2B


Accuracy of Perception - Influence of Condition on Frequency of Correct Identification
Frequency of Correct Identification
0
2
4
6
8
10
12
14
ORIG
B2B
EX
EXB2B
ASD
TD

Reaction Times of Ratings – Interaction Between CONTINGENCY*CONTEXT*GROUP.





Consistency of Perception - Influence of Manipulation Type on Mean Rating Deviation to Original Baseline
Mean Rating Deviation to Original Baseline
2
1
0
*
*
B2B_d
EX_d
EXB2B_d
ASD
TD